U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

2011 Geothermal Technologies Peer Review
Summary: Geothermal Cement

1. Development of an Improved Cement for Geothermal Wells

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2. Project Objectives and Purpose

Develop a novel, zeolite-containing lightweight, high temperature, high pressure geothermal cement, which will provide operators with an easy to use, flexible cementing system that saves time and simplifies logistics.

The cement to be developed would have the following characteristics:

1) Thermal stability with little strength retrogression to 300° C.
2) Tensile strength to withstand temperature and pressure changes.
3) Low-density, low-viscosity slurries with low equivalent circulating densities (ECD) without the need for air or nitrogen foaming.
4) A single cement blend allowing density adjustments without adversely affecting slurry properties to eliminate the need for separate blends for lead and tail slurries.
5) Resistance to carbonation.
6) Accurate downhole densities throughout cement placement without significant changes in viscosity.
7) Water absorption capacity without retaining free water.
8) Good bonding to casing and formation.
9) Adequate compressive strength.

The development of an improved cement for geothermal wells is necessary to achieve the vision and goals of the Geothermal Technologies Program (GTP) under the Multi-Year Research, Development, and Demonstration (MYRDD) plan. An improved geothermal cement is in keeping with Goal 2 of the MYRDD Technical Plan to develop low-cost, high-efficiency well construction which includes completion technology. Additionally, the development of an improved geothermal cement addresses Barrier C of the Site Selection Barriers. The MYRDD plan recognizes the current unsuitability of existing casing designs and materials for EGS and in particular the high cost of casing and cementing. A critical element of EGS is the creation of a reservoir by well stimulation which would most likely include hydraulic fracturing. The improved geothermal cement proposed has characteristics to withstand through-casing stimulation.

3. Technical Barriers and Targets

Cementing high temperature geothermal wells today is largely limited to methods based on a technology developed in the early 1990's by Brookhaven National Laboratory. This technology known as fly ash-modified calcium aluminate phosphate cement or CaP cement is described in US Patent 5,246,496 which was issued on September 21, 1995. Although CaP cements appear to perform effectively once placed they do have certain constraints which tend to increase cost and limit wide spread use. CaP cements exhibit sensitivity or in some cases incompatibility with common chemicals used as retarders or accelerators. In operating practices CaP cement cannot be contaminated with residual neat cement that may be "leftover" in pumping equipment from conventional completions. Operators, in effect, must "sterilize" equipment therefore increasing cost. CaP cement is pH sensitive as well as temperature sensitive. Operators have found that measured down-hole temperatures are critical in CaP cement batch formulation and that a variation in actual placement temperature verses batch formulation temperature can result in unpredictable setting time. Development of a zeolite-containing lightweight, high temperature, high pressure geothermal cement will provide operators with an easy to use, flexible cementing system that saves time and simplifies logistics. The requirement to "sterilize" pumping equipment before use, as with the CaP cement, will be eliminated.

The following properties are the primary criteria for initial cement formulation screening:

- Zero percent free water
- Rheological properties of less than 200 reading at 300 rpm
- 24 Hour compressive strength greater than 500 psi
- Thickening time and consistency, end thickening under 70 Bc
- Slurry density less than 13.5 lbs/gal

During the second stage of development the following tests will be performed:

- Rheological properties of cement slurry (shear stress versus shear rate)
- Slurry density measurement
- Slurry consistency and thickening time
- Compressive strength at 12 hour and 24 hour
- Tensile strength of set cement
- Percent free water measurement

- Response to retarders at high pressure and high temperature
- Quality of cement to casing bond
- Resistance to geothermal brines (long term stability)
- Compressive strength retrogression over a three to six month period
- Determination of the optimum blend ratio of silica flour and other additives to zeolite for thermal stability
- Permeability of set cement
- Poisson's ratio and Young's modulus of set cement
- Thermal conductivity of set cement

4. Technical Approach

The research and development is being conducted in five overlapping Tasks. These are:

TASK 1 – RESEARCH

Literature Search
Geothermal Cementing Practices and Constraints
Mechanisms of Geothermal Well Failure

TASK 2 – DESIGN

Compile Research Findings
Modification of Project Tasks 3 and 4

TASK 3 – DEVELOP

Zeolite Sample Acquisition
Zeolite Type Confirmation
Zeolite Particle Size Preparation
Initial Screening of Cement Formulations

TASK 4 – TEST

Second Stage Cement Development
Final Stage Cement Development

TASK 5 – DEMONSTRATE

Laboratory Scale Demonstration
Logistics and Ease of Use Field Demonstration – Chena Hot Springs Resort
High Temperature EGS Well Demonstration – Ormat Technologies

5. Technical Accomplishments

- Literature Search / Research

  During 2010 a comprehensive Literature Search was completed to gain an understanding and causes for well completion failure.

- Zeolite Acquisition

  During July 2010 1,000 pound zeolite samples to be used in the cement development were acquired from four western U.S. locations. The zeolites were; Chabazite, Clinoptilolite, Ferrierite and Analcime. These bulk sample zeolites were field crushed to a uniform minus 1/8 inch size and stored pending type confirmation.

- XRD / SEM

  X-ray diffraction, X-ray florescence and Scanning Electron Microscopic studies were completed by the University of Alaska Fairbanks to confirm zeolite type.

- Zeolite Preparation

  Following zeolite type confirmation three hundred pound splits of the bulk samples were shipped to CCE Technologies for preparation into the three sizes to be used in initial formulation screening. The zeolite sizes being used in initial blend tests are 5 microns, 10 microns and 44 microns.

- Class H Class G cement

  The two types of well cements being used in zeolite-containing cement formulations were acquired during 2010. These types are Class H and Class G. The Class H cement was supplied by Texas Lehigh Cement and the Class G cement by Lehigh Cement. A second Class G was obtained from Dykerhoff in Germany. The Dykerhoff cement will be compared to the U.S. Class G. Particle size distribution was completed for all cements.

6. Challenges to Date

XRD and SEM studies determined that the Analcime bulk sample was, in fact, not zeolite. The fact that the sample was not zeolite was disappointing but confirmed the protocol of making certain the zeolite type before actual screening formulation testing. After consideration it was determined to add a second Clinoptilolite from a different location to the screening study. The second, different location, Clinoptilolite will provide an indication of Clinoptilolite variability on screening formulation performance.

7. Conclusion and Plans for the future

The project is entering Task 3 / Element Four, Initial Screening of Cement Formulations. The variables in formulations are zeolite type, zeolite particle size, formulations using well cements Class H and Class G and multiple variations in percent zeolite by weight of cement. Following the identification of at least three zeolite-containing cement formulations the project will move into Task 4 and Second Stage Cement Development.

8. Publications and Presentations

Presentation - December 8, 2010 Anchorage, Alaska - Society of Petroleum Engineers, Alaska Section.

Presentation – March 9, 2011 Anchorage, Alaska – Alaska Department of Natural Resources.